



2003

Chemistry GA 1: Written examination 1

GENERAL COMMENTS

The overall performance on this examination was generally quite good, but there were particular areas on which significant numbers of students struggled to perform well under examination conditions.

Responses to questions relating to 'carbon' chemistry suggested that students need more practice in this area. Of particular concern were Question 8 in Section A and Question 3 in Section B, both testing structural formula of esters and understanding of the steps involved in ester formation.

Questions associated with pH continue to prove challenging. Question 3 in Section A – determine the pH of 0.0050 M Ba(OH)₂ – proved to be the 'most difficult' question in this section. In Question 6bi in Section B over one-third of students were unable to determine the (H⁺) in a solution given the pH. This may have been because of other data supplied in the question but is certainly an area to focus on.

Interpretation and explanation questions throughout Section B (2c, 2d, 4a, 5a, 6a) were not well done. In preparing for examinations students are encouraged to write more detailed responses to such questions.

Students should be exposed to a variety of questions to enable them to better handle 'different' questions. Question 1c, especially cii, in Section B was poorly done. Most students regarded the calculation of the concentration of NaCl in g L⁻¹ from the concentration of Na⁺ in mg L⁻¹ as simply a matter of dividing by 1000. This incorrect assumption that the mass of NaCl would be equal to the mass of Na⁺ needs to be addressed. However, students must also be instructed to take note of the number of marks allocated to each part of a question. Realisation that dividing by 1000 is unlikely to be awarded three marks may have prompted a different calculation strategy.

In questions where there is a large amount of data supplied students might benefit from using a highlighter or underlining key data and words. In Question 7 of Section B a number of students assumed or decided that 20.00 mL, rather than 22.00 mL, of 0.0510 M triiodide solution was used.

Section A – Multiple choice

This table indicates the approximate percentage of students choosing each distractor. The correct answer is the shaded alternative.

Question	A	B	C	D	Selected comments
1	7	80	7	6	The forward reaction is exothermic hence is favoured by low temperature. The forward reaction produces fewer particles hence is favoured by high pressure.
2	2	90	4	4	A catalyst speeds up the rate of reaction by decreasing the activation energy.
3	4	17	34	45	Ba(OH) ₂ (aq) → Ba ²⁺ (aq) + 2OH ⁻ (aq) [OH ⁻] = 2 x [Ba(OH) ₂] = 2 x 0.0050 = 0.010 M [H ₃ O ⁺] = 10 ⁻¹⁴ / 0.010 = 10 ⁻¹² M pH = -log ₁₀ (10 ⁻¹²) = 12 <i>This proved to be the most difficult question in Section A. Students who selected alternative C did not double the concentration of Ba(OH)₂, whilst those who selected B also did not find the concentration of H₃O⁺ before determining the pH.</i>
4	4	3	7	86	n(H ₂) = pV / RT = 0.125 x 100 / (8.31 x 300) = 0.0050 mol
5	9	24	5	62	When Zn, Ca and Mg react with HCl to produce H ₂ then M + 2HCl → MCl ₂ + H ₂ n(H ₂) produced = n(metal) reacting When Na reacts with HCl to produce H ₂ then 2Na + 2HCl → 2NaCl + H ₂ n(H ₂) produced = ½ x n(Na) reacting 0.12 g Zn → 0.12 / 65.4 = 0.0018 mol → 0.0018 mol H ₂ 0.12 g Na → 0.12 / 23.0 = 0.0052 mol → 0.0026 mol H ₂

0.12 g Ca $\rightarrow$ 0.12 / 40.0 = 0.0030 mol $\rightarrow$ 0.0030 mol H₂

0.12 g Mg $\rightarrow$ 0.12 / 24.3 = 0.0049 mol $\rightarrow$ **0.0049 mol H₂**

The popularity of alternative B may have been because students stopped at the first alternative which was close to the answer from Question 4 rather than getting to the point where a decision had to be made between B and D.

6	77	5	9	9	CH ₃ CH=CHCH ₃ + Br ₂ $\rightarrow$ CH ₃ CHBrCHBrCH ₃
7	9	65	16	10	$ \begin{array}{c} \text{CH}_3 \text{ H} \\ \quad \\ \text{C} = \text{C} \\ \quad \\ \text{H} \quad \text{CH}_3 \end{array} + \begin{array}{c} \text{CH}_3 \text{ H} \\ \quad \\ \text{C} = \text{C} \\ \quad \\ \text{H} \quad \text{CH}_3 \end{array} \rightarrow \begin{array}{c} \text{CH}_3 \text{ H} \quad \text{CH}_3 \text{ H} \\ \quad \quad \quad \\ -\text{C}-\text{C}-\text{C}-\text{C}- \\ \quad \quad \quad \\ \text{H} \quad \text{CH}_3 \quad \text{H} \quad \text{CH}_3 \end{array} $
8	18	49	19	14	CH ₃ CH=CHCH ₃ + H ₂ O $\rightarrow$ CH ₃ CH ₂ CHOHCH ₃ 2-butene is converted into 2-butanol 2-butanol then reacts with ethanoic acid to produce an ester CH ₃ COOH + HOCHCH ₂ CH ₃ $\rightarrow$ CH ₃ COOCHCH ₂ CH ₃ $ \begin{array}{c} \text{CH}_3 \\ \\ \text{CH}_3\text{COOH} \end{array} + \begin{array}{c} \text{CH}_3 \\ \\ \text{HOCHCH}_2\text{CH}_3 \end{array} \rightarrow \begin{array}{c} \text{CH}_3 \\ \\ \text{CH}_3\text{COOCHCH}_2\text{CH}_3 \end{array} $ <i>This question proved to be one of the most difficult ones in Section A. Students should be aware that the addition reaction between an alkene and water produces an alcohol and alcohols react with carboxylic acids to form esters.</i>
9	4	1	94	1	$K = \frac{[\text{F}_2]^3[\text{Cl}_2]}{[\text{ClF}_3]^2}$
10	19	6	64	11	The forward reaction is exothermic, so lowering the temperature favours the forward reaction and 0.010 mol ClF ₃ is used up. According to 2ClF ₃ $\rightarrow$ 3F ₂ + Cl ₂ 0.010 mol ClF ₃ $\rightarrow$ 0.015 mol F ₂ and 0.00050 mol Cl ₂ <i>Students who selected alternative A had the stoichiometry correct but misinterpreted the effect of lowering the temperature. Students who selected alternative D inverted the mole ratios, an unexpected error at this level.</i>
11	10	5	5	80	Cracking of alkanes can produce alkenes, smaller alkanes and hydrogen. <i>It is unlikely that 20 per cent of students believe that it is possible to produce CO₂ from alkanes in the absence of air. The popularity of alternative A suggests that many students linked 'cracking' and 'alkenes' and overlooked the 'not' in the question despite it being clearly emphasised.</i>
12	79	3	11	7	The only alternative with the same molecular formula, i.e. C ₃ H ₆ O ₂ was HCOOCH ₂ CH ₃ <i>Some students clearly did not make the distinction between propanoic acid, CH₃CH₂COOH and ethyl methanoate, HCOOCH₂CH₃. Alternatives B, C and D all had more carbon or hydrogen atoms than CH₃CH₂OH and so could not be structural isomers.</i>
13	3	21	70	6	3-nonanol $\rightarrow$ 9 C atoms with -OH on carbon number 3. CH ₃ CH ₂ CH ₂ CH ₂ CH ₂ CH ₂ CHOHCH ₂ CH ₃ $\rightarrow$ 20 H atoms <i>Students are expected to be familiar with systematic names (and structural formulae) for straight chain compounds containing up to 10 C atoms.</i>
14	2	13	18	67	4 structural isomers CH ₃ CH ₂ CH ₂ CH ₂ Cl, 1-chlorobutane CH ₃ CH ₂ CHClCH ₃ , 2-chlorobutane (CH ₃) ₂ CHCH ₂ Cl, 2-methyl-1-chloropropane (CH ₃) ₃ CHCl, 2-methyl-2-chloropropane <i>Familiarity with structural isomers containing up to four C atoms is expected.</i>
15	57	12	16	15	N ₂ + O ₂ $\rightleftharpoons$ 2NO; K ₁ = 5 $\times$ 10 ⁻³ 2NO $\rightleftharpoons$ N ₂ + O ₂ ; K ₂ = 1 / K ₁ = 1 / 5 $\times$ 10 ⁻³ = 2 $\times$ 10 ² 4NO $\rightleftharpoons$ 2N ₂ + 2O ₂ ; K ₃ = K ₂ ² = (2 $\times$ 10 ²) ² = 4 $\times$ 10 ⁴ <i>An improved performance compared to a similar question on the 2002 examination.</i>
16	14	30	46	10	The presence of the smell suggests that there are volatile substances in the

paper from which journal is produced. The volatile components would best be separated and analysed by gas-liquid chromatography.

The popularity of alternative B may suggest students did not make the link between the 'smell' and the presence of volatile compounds. Students should be aware of the common uses of analytical techniques.

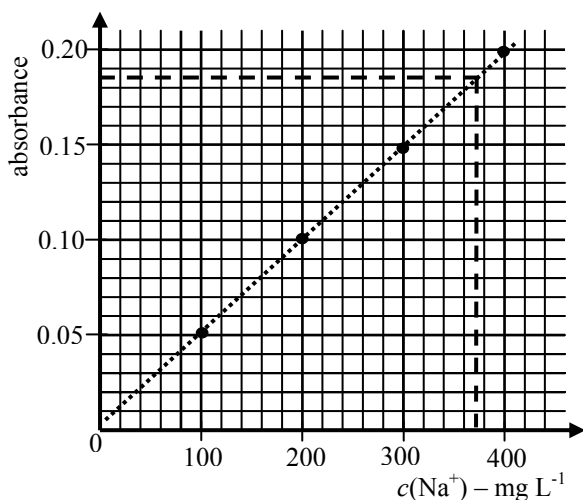
17	16	67	9	8	HCl(aq), HNO₃(aq) and HClO₄(aq) are all strong monoprotic acids. For equal masses the acid with the lowest molar mass will have the highest $n(\text{acid})$ and hence produce the highest $n(\text{H}^+)$, highest $[\text{H}^+]$ and lowest pH $M(\text{HCl}) = 36.5 \text{ g mol}^{-1}$ $M(\text{HNO}_3) = 63 \text{ g mol}^{-1}$ $M(\text{HClO}_4) = 100.5 \text{ g mol}^{-1}$ So HCl will produce the solution with lowest pH. <i>A high number of students selected alternative A. Students are expected to know that NH₃ is a base and bases form solutions of higher pH than do acids.</i>																																				
18	92	2	3	3	$\text{H}(+1)\text{Cl}(x)\text{O}(-2)_4 \rightarrow +1 + x + 4(-2) = 0 \rightarrow x = +7$																																				
19	4	16	16	64	<table><tr><td></td><td>C</td><td>:</td><td>H</td></tr><tr><td>mass ratio</td><td>81.8 g</td><td>:</td><td>18.2 g</td></tr><tr><td>mole ratio</td><td>81.8/12.0</td><td>:</td><td>18.2/1.0</td></tr><tr><td></td><td>6.82</td><td>:</td><td>18.2</td></tr><tr><td>simplest ratio</td><td>6.82/6.82</td><td>:</td><td>18.2/6.82</td></tr><tr><td></td><td>1</td><td>:</td><td>2.67</td></tr><tr><td></td><td>1</td><td>:</td><td>2²/3</td></tr><tr><td></td><td>1</td><td>:</td><td>8/3</td></tr><tr><td></td><td>3</td><td>:</td><td>8</td></tr></table> Empirical Formula C₃H₈ <i>Students who selected alternatives B and C probably rounded off the ratios 1:2.67 to 1:3 and 1:2.5 respectively.</i>		C	:	H	mass ratio	81.8 g	:	18.2 g	mole ratio	81.8/12.0	:	18.2/1.0		6.82	:	18.2	simplest ratio	6.82/6.82	:	18.2/6.82		1	:	2.67		1	:	2 ² /3		1	:	8/3		3	:	8
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20	15	17	46	22	C₆H₁₂O₆ is clearly dehydrated to C when reacting with sulfuric acid. H₂SO₄ acts as an acid in donating a proton to H₂O to produce H₃O⁺ and HSO₄⁻. <i>The selection of alternative D by 22 per cent of students indicated that a significant number of students considered the reaction to be a redox reaction. Whilst concentrated sulfuric acid is a good oxidant there is no evidence of it acting as such in this reaction. When concentrated sulfuric acid acts as an oxidant the oxidation number of sulfur decreases; this does not happen in the reaction shown.</i>																																				

Section B – Short answers

Question 1

1a

Marks	0	1	Average
%	20	80	0.80



Students were expected to plot all points accurately vertically; with ± 0.005 (half a division) allowed horizontally.

1b

Marks	0	1	2	Average
%	19	37	44	1.25

$$c(\text{Na}^+) \text{ in diluted sauce} = 372 \pm 5 \text{ mg L}^{-1}$$

$$c(\text{Na}^+) \text{ in original sauce} = (1000/25) \times 372$$

$$= 1.49 \times 10^4 \text{ mg L}^{-1}$$

Students were awarded 1 mark for correctly reading their graph from (a) even if that graph was inaccurate. The second mark, for multiplying the figure from the graph by 40 – the original dilution factor – was missed by many students who divided by 40 instead.

1ci–iii

Marks	0	1	2	3	4	5	6	Average
%	35	17	24	14	2	4	4	1.57

1ci

all the Na^+ in the sauce is present as NaCl or NaCl was the only source of Na^+ ions

1cii

$$m(\text{Na}^+) \text{ in 1 L} = 1.49 \times 10^4 \text{ mg} = 14.9 \text{ g}$$

$$n(\text{Na}^+) = 14.9 \text{ g} / 23.0 = 0.65 \text{ mol}$$

$$n(\text{NaCl}) = n(\text{Na}^+) = 0.65 \text{ mol}$$

$$m(\text{NaCl}) = 0.65 \times 58.5 = 38 \text{ g in 1.00 L}$$

$$c(\text{NaCl}) = 38 \text{ g L}^{-1}$$

1ciii

$$m(\text{NaCl}) \text{ consumed} = (10 / 1000) \times 38$$

$$= 0.38 \text{ g (in 10 mL)}$$

$$\% \text{ of RDI} = (0.38 / 2.5) \times 100 = 15 \%$$

This question proved challenging for the majority of students. Responses to part (i) suggested difficulties in understanding the analytical process. The most common response to part (ii) indicated that many students assumed the masses of Na^+ and NaCl were equal and simply converted their second answer from part (b) from mg L^{-1} to g L^{-1} (this received no marks). The fact that $n(\text{Na}^+) = n(\text{NaCl})$ was overlooked. Students were awarded full marks if their answer was correct based on their answer to part (b). Most students who had an answer to part (ii) used it successfully in part (iii).

1d

Marks	0	1	2	Average
%	49	21	30	0.81

The light source used in the AAS emits wavelengths unique (or specific) to Na / Na^+ . So the selected wavelength will only be absorbed by Na / Na^+ .

Responses suggested that many students did not appreciate the significance of the light source in AAS nor the difference between AAS and UV-Vis spectroscopy.

Question 2

2a

Marks	0	1	Average
%	19	81	0.81

Some O_2 was added to the container.

Responses of 'increased pressure' and 'addition of a catalyst' were surprisingly common.

2b

Marks	0	1	Average
%	13	87	0.87

X – SO_3 , Y – SO_2

2c

Marks	0	1	2	3	Average
%	15	9	22	54	2.15

Upon addition of O_2 , the position of equilibrium moves to the right (there is a net forward reaction), hence the amount of SO_3 (or X) will increase and the amounts of SO_2 (or Y) will decrease and O_2 will decrease (or net increase).

Many students identified or partially identified the changes that occurred but overlooked the **explanation** that the changes were associated with the position of equilibrium moving to the right.

2d

Marks	0	1	2	Average
%	41	9	50	1.09

The temperature will increase because the forward reaction is exothermic.

No mark was awarded if a student simply stated that the forward reaction was exothermic.

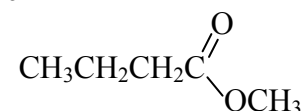
Question 3

3a

Marks	0	1	Average
%	48	52	0.52



or

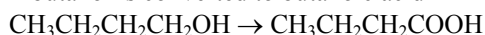


Students need to practise writing formulae (structures) for esters other than ethyl ethanoate.

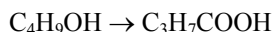
3b

Marks	0	1	2	3	Average
%	39	15	17	29	1.37

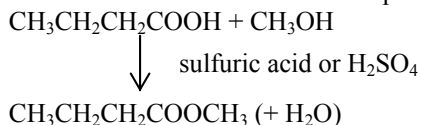
1-butanol is converted to butanoic acid



or



Butanoic acid is reacted with methanol to produce the ester



Students need more practice in applying 'the general reaction for the formation of an ester'. Deducing that methyl butanoate is produced from methanol and butanoic acid should lead to the realisation that 1-butanol needed to be converted to butanoic acid. Students were asked to give the 'name' of the catalyst used but significant numbers wrote the formula H_2SO_4 instead of sulfuric acid. Whilst this was awarded the allocated mark students should be instructed to provide answers in the stated form.

Question 4

4a

Marks	0	1	2	Average
%	24	7	69	1.44

Weak acid – only partially ionises (donates few H^+ ions/protons) in water.

Strong acid – completely ionises (donates many H^+ ions/protons) in water.

A significant number of students attempted to use pH as the means of distinguishing between weak and strong acids. The effect of acid concentration on pH is worth discussion.

4b

Marks	0	1	Average
%	11	89	0.89

$$K_a = \frac{[\text{HCOO}^-][\text{H}^+]}{[\text{HCOOH}]}$$

4c

Marks	0	1	2	Average
%	32	11	57	1.25

$$\begin{aligned}
 [\text{HCOOH}] &= 0.10 \text{ M}; [\text{H}^+] = [\text{HCOO}^-] \\
 1.8 \times 10^{-4} &= [\text{H}^+]^2 / 0.10 \rightarrow [\text{H}^+]^2 = 1.8 \times 10^{-4} \times 0.10 \\
 [\text{H}^+] &= \sqrt{(1.8 \times 10^{-5})} \\
 &= 4.2 \times 10^{-3} \text{ M} \\
 [\text{HCOO}^-] &= 4.2 \times 10^{-3} \text{ M}
 \end{aligned}$$

Question 5

5a

Marks	0	1	2	3	Average
%	14	41	16	29	1.59

5ai

By working out the ratio of the 'distance moved by the substance from the origin (zero point/initial spot)' to the 'distance moved by the solvent front the origin (zero point/initial spot)'.

5a ii

Origin (zero point / initial spot) is located at 2.7 cm

$$\begin{aligned}
 R_f &= (17.4 - 2.7) / (28.8 - 2.7) \\
 &= 14.7 / 26.1 \\
 &= \mathbf{0.56 \pm 0.02}
 \end{aligned}$$

One mark was awarded in **ai** if the R_f value was calculated without subtracting the origin value, i.e. $R_f = 17.4 / 28.2$. A significant number of students did not refer to the origin in their answers to **ai** but clearly used the origin in their calculations to **a ii**. These students were awarded full marks if their answer to **a ii** was correct. Students who showed no appreciation of the role of the origin in **ai** or **a ii** were effectively limited to a maximum of 1 mark.

5b

Marks	0	1	Average
%	25	75	0.75

The mixture was added with a capillary tube or dropping pipette **or** as a small drop at the zero point/initial spot. Many students struggled to explain this simple practical technique.

5c

Marks	0	1	2	Average
%	22	31	47	1.25

The relative extent of the attraction of the amino acids to the stationary phase (paper)/(adsorption to the stationary phase) and their attraction to the mobile phase (solubility in the mobile phase).

Question 6

6a

Marks	0	1	2	3	Average
%	23	15	21	41	1.81

Increasing $[\text{CO}_2(\text{g})]$ pushes the first equilibrium to the right increasing the $[\text{CO}_2(\text{aq})]$ *or* mention of Le Chatelier's principle.

Increasing $[\text{CO}_2(\text{aq})]$ pushes the second equilibrium to the right increasing the $[\text{H}^+(\text{aq})]$.

Increasing $[\text{H}^+(\text{aq})]$ causes the pH to decrease.

The requirement to explain or link the sequence of changes together proved challenging for many students. In this type of question, 3 marks usually implies that three distinct points need to be made. Some students correctly identified the increase in acidity of the solution but faltered on the pH change.

6b

Marks	0	1	2	3	Average
%	37	25	5	33	1.33

6bi

$$\text{pH} = 7.4 \rightarrow [\text{H}^+] = 10^{-7.4} \text{ M or } 4.0 \times 10^{-8} \text{ M}$$

6bii

$$\begin{aligned}
 K_a &= [\text{H}^+][\text{HCO}_3^-] / [\text{CO}_2] \\
 7.9 \times 10^{-7} &= 4.0 \times 10^{-8} \times [\text{HCO}_3^-] / 1.3 \times 10^{-5}
 \end{aligned}$$

$$[\text{HCO}_3^-] = 7.9 \times 10^{-7} \times 1.3 \times 10^{-5} / 4.0 \times 10^{-8} \\ = 2.6 \times 10^{-4} \text{ M}$$

In **bi** many students ignored the given pH and attempted to calculate the $[\text{H}^+]$ by using the K_a as per question **4c**. This impacted on their progress in **bii**.

Question 7

7a

Marks	0	1	2	3	Average
%	38	9	33	20	1.35

$$n(\text{H}_2\text{C}_2\text{O}_4) \text{ in } 20 \text{ mL} = n(\text{I}_3^-) = 0.0510 \times 22.00 \times 10^{-3} \\ = 1.12 \times 10^{-3} \text{ mol}$$

$$n(\text{H}_2\text{C}_2\text{O}_4) \text{ in } 100 \text{ mL} = 100 / 20 \times 1.12 \times 10^{-3} \\ = 5.60 \times 10^{-3} \text{ mol } (5.61 \times 10^{-3})$$

The most common error was the 100/20 factor. A number of students confused the 20.00 mL of resulting solution and the 22.00 mL of 0.0510 M triiodide solution.

7b

Marks	0	1	2	Average
%	35	19	46	1.10

$$n(\text{H}_2\text{C}_2\text{O}_4) \text{ initially} = 0.150 \times 100 \times 10^{-3} \\ = 1.50 \times 10^{-2} \text{ mol}$$

$$n(\text{H}_2\text{C}_2\text{O}_4) \text{ used} = n(\text{H}_2\text{C}_2\text{O}_4) \text{ initially} - n(\text{H}_2\text{C}_2\text{O}_4) \text{ remaining} \\ = 1.50 \times 10^{-2} - 5.60 \times 10^{-3} \\ = 9.40 \times 10^{-3} \text{ mol } (9.39 \times 10^{-3})$$

Students whose answer to part **a**. was incorrect were awarded full marks in this part if that answer was used appropriately.

7c

Marks	0	1	2	Average
%	42	11	47	1.04

$$n(\text{MnO}_2) \text{ present} = n(\text{H}_2\text{C}_2\text{O}_4) \text{ reacting} \\ = 9.40 \times 10^{-3} \text{ mol}$$

$$m(\text{MnO}_2) \text{ present} = 9.40 \times 10^{-3} \times 86.9 \\ = 0.816 \text{ g}$$

$$\% \text{ MnO}_2 = (0.816 / 1.25) \times 100 \\ = 65.3 \%$$

Full marks were awarded as long as the answer to **b**. was correctly used. Significant figures were assessed over all three parts of Question 7.

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